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Physical and mechanical properties of milk thistle seeds

A.N. Lorestani*, **R. Gholami and M. Zareie**

Razi University, Faculty of Agriculture, Mechanical Engineering of Agricultural Machinery Department, Imam Khomeini Highway, 6715685438 Kermanshah, Iran; ali.lorestani@gmail.com

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RESEARCH ARTICLE

Abstract

Physical and mechanical properties of medicinal plants and agricultural products are important for the design of harvesting and processing equipment. In this paper, the physical and mechanical properties of milk thistle were investigated. The physical properties that were measured included dimensions (big, medium and small diameters), aspect ratio, geometric mean diameter, arithmetic means diameter, projected area, surface area, sphericity, moisture, density and porosity. Their averages were found to be 6.52 mm, 3.13 mm, 1.81 mm, 48.15%, 3.33 mm, 3.82 mm, 13.65 mm^2, 88.04 mm^2, 51%, 6.87%, 0.77 g/cm^3 and 87.5%, respectively. Mechanical properties such as modulus of elasticity, maximum force that the fruit can support, work associated with this force, deformation under compression loading and hardness were investigated and their average values were found to be 0.49 GPa, 136.41 N, 64.39 N.mm, 0.77 mm and 215.96 N/mm, respectively. The coefficient of static friction of samples was measured on three surfaces (glass, galvanised metal and wood), and their average vales were found to be 0.38, 0.37, 0.37, respectively.

Keywords: milk thistle, physical and mechanical properties

1. Introduction

Milk thistle (*Silybum marianum*) seeds have been used for almost 2,000 years as a natural medicament for the liver and biliary duct. Silymarin is a pharmacologically effective substance containing four main constituents: (1) silybin (50-60%); (2) isosilybin (5%); (3) silychristin (20%); and (4) andsilydianin (10%) (Suchy *et al.*, 2008). It is beginning to be used to protect against nephrotoxicity. It protects the liver from several hepatotoxins, including amanita mushrooms, acetaminophen and alcohol. Its primary active ingredient is silymarin, which is a potent antioxidant composed of several flavonoid compounds. Ripe milk thistle seeds are used in Europe in the treatment of various hepatobiliary problems, such as hepatitis, cirrhosis, gallstones, and jaundice, as well as for kidney ailments (Fintelmann, 1991). Milk thistle is used as an antidote for amanita mushroom poisoning and to protect the liver and kidneys from toxic medications (Flora *et al.*, 1998). It is used to treat hepatitis and biliary disease, lower cholesterol, and even improves psoriasis. It also has antiviral, antitumor and other therapeutic properties. Milk thistle preparations are safe, well tolerated and cause no serious side effects except mild gastrointestinal and allergic reactions. Milk thistle seed is a very promising herbal drug. More research is warranted to substantiate its broad ranging phytotherapeutic effects (Bhattacharya, 2011).

For designing equipment for harvesting and post-harvesting technology such as storing, transporting, sizing, cleaning, packaging, separating and processing, knowing the physical and mechanical properties of the milk thistle seeds are important. Since currently used systems have been generally designed without taking these criteria into consideration, the resulting designs lead to inadequate applications. Results of this design are a reduction in efficiency and an increase in product loss. Therefore, the determination and consideration of these criteria have an important role in designing of harvesting and post-harvesting equipment.

There have been a lot of studies on the physical and mechanical properties of some agricultural products, such as the mechanical properties of Tarocco orange fruit under parallel plate compression (Pallottino *et al.*, 2011), and the physical and mechanical properties of zucchini (summer squash) as investigated by Gholami *et al.* (2012). Also the physical and mechanical properties of oak (*Quercus persica*) fruits (Jalilian *et al.*, 2011), Egyptian onion (Bahnasawy *et al.*, 2004), olive fruits (Kilickan and Guner, 2008), cooked red bean (Legrand *et al.*, 2007), aonla fruits (Goyal *et al.*, 2007), okra fruit (Owolarafe and Shotonde, 2004), kiwi fruit (Lorestani and Tabatabaeefar, 2006), fava bean (Lorestani and Ghari, 2012), castor seed (Lorestani *et al.*, 2012) and wild plum (Calisir *et al.*, 2005) have been studied. As well as the effect of moisture content on some physical and mechanical properties of faba bean grains (Altuntas and Yildiz 2007), and the determination of physical, mechanical and chemical properties of seeds and kernels of Jatropha (Karaj and Muller 2010).

Despite an extensive search, no published literature was found on the detailed physical and mechanical properties of milk thistle. The aim of this study was to determine the physical properties and mechanical behaviour of milk thistle (*S. marianum*) under compression.

2. Materials and methods

Physical properties

In this research 70 milk thistle seeds were collected from Kermanshah province in the west of Iran (Figure 1). In this study some physical properties such as the dimensions (big, medium and small diameters), aspect ratio, geometric mean diameter, arithmetic means diameter, projected area, surface area, sphericity, moisture, density and porosity were determined. Dimensions of the seeds were measured using a micrometre to an accuracy of 0.01 mm. The mass of seeds was measured with an electronic balance (Shimadzu Corporation, Kyoto, Japan) to an accuracy of 0.01 g. The three important measured characteristics were maximum, mean and minimum projected areas (perpendicular to thickness, width and length, respectively). These were measured by a Delta-T area-meter, model MK2, with 0.1 accuracy (Delta-T Devices Ltd., Cambridge, UK).

Figure 1. Samples of milk thistle (*Silybum marianum*) seeds.

The geometric mean diameter (D_g), sphericity (ϕ), arithmetic means diameter (D_a) values were determined using the following equations (Guner *et al.*, 2003; Mohsenin, 1986):

$$D_a = \frac{a+b+c}{3} \quad (1)$$

$$D_g = (a \cdot b \cdot c)^{1/3} \quad (2)$$

$$\phi = \frac{D_g}{a} \times 100 \quad (3)$$

Where a, b and c are big, medium and small diameters, respectively.

The surface area (S) of milk thistle seeds was found by analogy with a sphere of the same geometric mean diameter, using the expression cited by Olajide and Ade-Omowaye (1999):

$$S = \pi(D_g)^2 \quad (4)$$

The aspect ratio (R_a) that is recommended by Owolarafe and Shotonde (2004) was obtained by using the following relationship:

$$R_a = (b/a) \times 100 \quad (5)$$

The moisture content was determined using standard methods (Altuntas and Yildiz, 2007). The initial moisture content of the samples was determined by oven drying at 104 °C for 24 h and calculated by the following equation:

$$\%mc = \frac{m-m_0}{m_0} \times 100 \quad (6)$$

Where, mc is the moisture content (% on dry basis), and m (g) and m_0 (g) are the mass of samples before and after putting them in the oven, respectively.

The true volume and true density were determined by the liquid displacement method (Mohsenin, 1986). Water was used for this purpose. The true volume (V) was calculated with the following equation:

$$V = \frac{M_a - M_w}{\rho_w} \quad (7)$$

Where M_w is the mass of a sample in water (g), M_a is the mass of a sample in air (g), V is the true volume of samples (cm^3) and ρ_w is the density of water (g/cm^3). Then, the true density of milk thistle seed was obtained by the following relationship:

$$\rho_t = M_a/V \quad (8)$$

Where ρ_t is the true density (g/cm^3) of samples.

The bulk density was determined by filling an empty 160 ml graduated cylinder with the seed and weighed. The weight of the seeds was obtained by subtracting the weight of the cylinder from the weight of the cylinder and milk thistle seeds. To achieve uniformity in bulk density the graduated cylinder was tapped 2 times for the milk thistle seeds to consolidate.

The volume occupied was then noted. The process was replicated four times and the bulk density for each replication was calculated from the following relation:

$$\rho_b = W_b/V_b \quad (9)$$

Where ρ_b is the bulk density (g/ml), W_b is the weight of the sample (g) and V_b is the volume occupied by the sample (mm^3).

The porosity of milk thistle seeds was determined using the relationship that is recommended by Mohsenin (1986):

$$\%\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (10)$$

Where ε is the porosity of milk thistle seeds (%).

Finally, the coefficient of static friction of samples was measured using an electrical friction tester (Lorestani *et al.*, 2012; Figure 2) on three surfaces (glass, galvanised metal and wood).

Mechanical behaviour

The mechanical properties and mechanical behaviour were determined with a compression loading test. The samples were placed under compression in a loading test. The elastic modulus, the maximum force that the seed can support, the work associated with this maximum force and the seed deformation when subjected to this maximum force under compression loading were determined using the Zwick/Roell universal testing machine (Zwick GmbH & Co. KG, Ulm, Germany) equipped with a 500 N compression load cell (Figure 3). The samples were placed on the fixed plate and loaded with a moving plate with 10 mm/min speed. The measurement accuracy was 0.001 N. Force deformation curves were recorded by its software. Some mechanical properties were determined from force deformation curves and other properties were calculated for every direction.

Hardness (H; N/mm) is the ratio of maximum force and deformation at this force. It was calculated as:

$$H = \frac{F_{max}}{\delta} \quad (11)$$

Where F_{max} is the maximum force and δ is the deformation of seeds when subjected to this maximum force.

Statistics

Experimental data were analysed using analysis of variance (ANOVA), and the means were separated at the 1% probability level by applying Duncan's multiple range tests in SPSS 17 (SPSS Inc., Chicago, IL, USA).

Figure 2. Electrical friction tester.

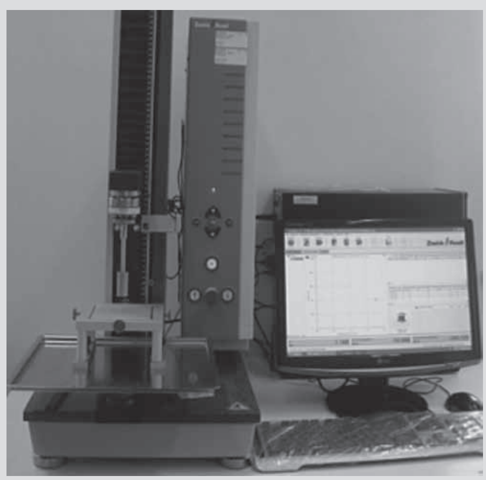

Figure 3. Zwick/Roell universal testing machine.

3. Results and discussion

The dimensions (big, medium and small diameters) of milk thistle seeds vary within the ranges of 5.75-7.31 mm, 2.64-3.75 mm and 0.8-2.21 mm, respectively, as shown in Table 1. The arithmetic mean and geometric mean diameters of milk thistle seeds were 3.06-4.42 mm and 2.30-3.92 mm, respectively (Table 1). As Equations 1 and 2 show, there is a relationship between the arithmetic and geometric mean diameters calculated from the dimensions. This relationship is shown in Figure 4. The correlation coefficient (R^2) was 0.9083. Therefore, one of these parameters can be calculated from the other with a high degree of confidence. Bal and Mishra (1988) and Dutta *et al.* (1988) considered the grain as spherical when the sphericity value was more than 0.80 and 0.70%, respectively. Therefore, milk thistle seeds may not be treated as an equivalent sphere for calculation of the surface area, because the sphericity of milk thistle seeds that was calculated in this study lay between 40-54%.

The values for the coefficient of static friction are shown in Table 2. It can be clearly seen that the value of the coefficient of static friction on glass is the greatest. This is important in post-harvest technology.

The mechanical behaviour of milk thistle seeds are shown in Table 3. The maximum force that each sample can support, the work that is associated with this force, the deformation to this force and the hardness properties that were measured under compression are shown.

Table 1. Physical properties of milk thistle seeds.

Physical properties	Number of replications	Mean	Maximum	Minimum	SD	CV%
Big dimension (mm)	70	6.52	7.31	5.75	0.36	5.47
Medium dimension (mm)	70	3.13	3.75	2.64	0.22	7.05
Small dimension (mm)	70	1.81	2.21	0.8	0.28	15.38
Aspect ratio (%)	70	48.15	60.58	39.29	3.81	7.90
Projected area (mm^2)	70	13.65	16	6.9	1.51	11.10
Arithmetic means diameter (mm)	70	3.82	4.42	3.06	0.19	5.01
Sphericity (%)	70	51	54	40	0.04	7.04
Surface area (mm^2)	70	88.04	132.64	35.19	4.70	5.34
Geometric mean diameter (mm)	70	3.33	3.92	2.30	0.23	7.06
True density (g/cm^3)	15	0.77	0.85	0.65	0.06	8.89
Porosity (%)	-	87.5	88.65	85.67	1.22	1.39
Moisture content (%)	20	6.87	7.09	6.21	-	-

CV% = coefficient of variance; SD = standard deviation.

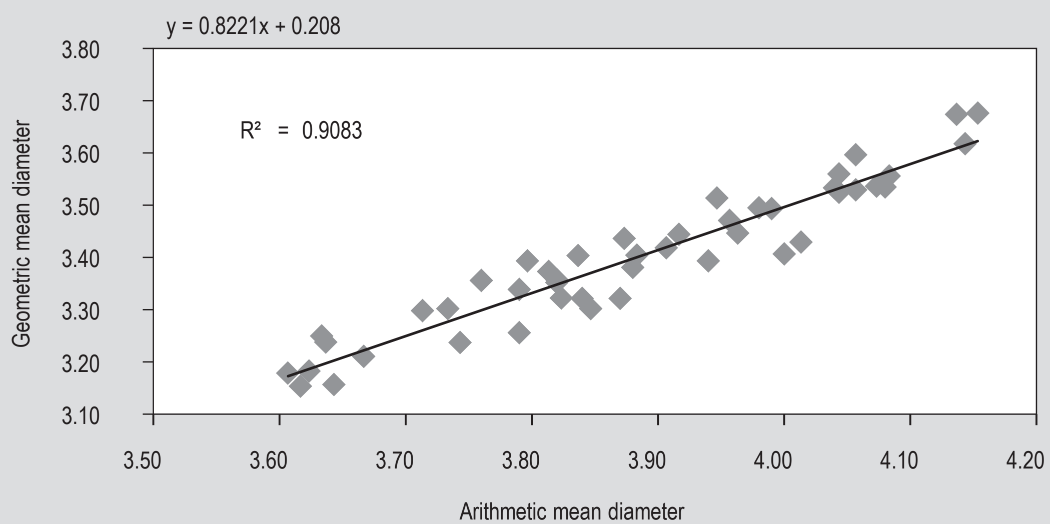

Figure 4. Relationship between arithmetic and geometric mean diameter.

Table 2. Static coefficient of friction of milk thistle seeds.

Surface	Mean	Maximum	Minimum	SD	CV%
Glass	0.38	0.39	0.36	0.02	0.04
Galvanized metal	0.37	0.38	0.36	0.01	0.02
Wood	0.37	0.39	0.34	0.03	0.08

CV% = coefficient of variance; SD = standard deviation.

Table 3. Mechanical properties of milk thistle seeds determined under vertical loading.

Mechanical properties	Mean	Maximum	Minimum	SD	CV%
Elasticity modulus (GPa)	0.49	0.7	0.27	0.13	26.43
F_{max} (N)	136.41	199	72.40	49.94	36.61
W to F_{max} (N.mm)	64.39	139.95	20.64	48.21	74.88
dl to F_{max}	0.77	1.50	0.20	0.45	58.10
Hardness (N/mm)	215.96	433.50	95.71	84.98	39.35

CV% = coefficient of variance; dl = deformation to maximum force under compression loading; F_{max} = maximum force that the seed can support; SD = standard deviation; W = work performed to maximum force.

4. Conclusions

For post-harvest technology such as grading, transporting, packaging, sorting, processing, etc., knowledge of the physical properties and mechanical behaviour of medicinal plants and agricultural products is necessary. In this study, physical and mechanical properties of milk thistle seeds, such as dimensions (big, medium and small diameters), geometric mean diameter, projected area, surface area, arithmetic mean diameter, aspect ratio, sphericity, moisture, porosity, density, elastic modulus, the maximum force that seed can support, the work associated with this force, the deformation at this force, and the hardness under compression loading were determined. These data will facilitate design of equipment and of machinery for the production that may reduce damage to the products.

References

Altuntas, E. and Yildiz, M., 2007. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. Journal of Food Engineering 78: 174-183.

Bahnasawy, A.H., El-Haddad, Z.A., El-Ansary, M.Y. and Sorour, H.M., 2004. Physical and mechanical properties of some Egyptian onion cultivars. Journal of Food Engineering 62: 255-261.

Bal, S. and Mishra, H.N., 1988. Engineering properties of soybean. In: Ali, N., Gandhi, A.P. and Ojha, T.P (eds.). Proceedings of the National Seminar on Soybean Processing and Utilization in India. November 22-23, 1986. Central Institute of Agricultural Engineering, Bhopal, India, pp. 146-165.

Bhattacharya, S., 2011. Phytotherapeutic properties of milk thistle seeds: an overview. Journal of Advanced Pharmacy Education and Research 1: 69-79.

Calisir, S., Haciseferoglu, H., Ozcan, M. and Arslan, D., 2005. Some nutritional and technological properties of wild plum (*Prunus* spp.) fruits in Turkey. Journal of Food Engineering 66: 233-237.

Dutta, S.K., Nema, V.K. and Bhardwaj, R.K., 1988. Physical properties of gram. Journal of Agricultural Engineering Research 39: 259-268.

Fintelmann V., 1991. Modern phytotherapy and its uses in gastrointestinal conditions. Planta Medica 57: S48-S52.

Flora, K., Hahn, M., Rosen, H. and Benner, K., 1998. Milk thistle (*Silybum marianum*) for the therapy of liver disease. American Journal of Gastroenterology 93: 139-43.

Gholami, R., Lorestani, A.N., Jaliliantabar, F., 2012. Determination of physical and mechanical properties of zucchini (summer squash). Agricultural Engineering International: CIGR Journal 14: 1.

Goyal, R.K., Kingsly, A.R.P., Kumar, P. and Walia, H., 2007. Physical and mechanical properties of aonla fruits. Journal of Food Engineering 82: 595-599.

Guner, M., Dursun, E. and Dursun, I.G., 2003. Mechanical behaviour of hazelnut under compression loading. Biosystems Engineering 85: 485-491.

Jalilian, F., Lorestani, A.N., Gholami, R., Behzadi, A. and Fereidoni, M., 2011. Physical and echanical properties of oak (*Quercus persica*) fruits. Agricultural Engineering International: CIGR Journal 13: 4.

Karaj, S. and Muller, J., 2010. Determination of physical, mechanical and chemical properties of seeds and kernels of *Jatropha curcas* L. Industrial Crops and Products 32: 129-138.

Kilickan, A. and Gunner, M., 2008. Physical properties and mechanical behavior of olive fruits (*Olea europaea* L.) under compression loading. Journal of Food Engineering 87: 222-228.

Legrand, A., Leuliet, J.C., Duquesne, S., Kesteloot, R., Winterton, P. and Fillaudeau, L., 2007. Physical, mechanical, thermal and electrical properties of cooked red bean (*Phaseolus vulgaris* L.) for continuous ohmic heating process. Journal of Food Engineering 81: 447-458.

Lorestani, A.N. and Ghari, M., 2012. Mass modeling of fava bean (*Vicia faba* L.) with some physical characteristics. Scientia Horticulturae 133: 6-9.

Lorestani, A.N., Jaliliantabar, F. and Golami, R., 2012. Physical and mechanical properties of castor seed. Quality Assurance and Safety of Crops and Foods 4: e29-e32.

Lorestani, A.N., Rabani, R.H. and Khazaei, Y., 2012. Design and construction of an automatic coefficient of friction measuring device. Agricultural Engineering International: CIGR Journal 14: 120-124.

Lorestani, A.N. and Tabatabaeefar, A., 2006. Modeling the mass of kiwi fruit by geometrical attributes. International Agrophysics 20: 135-139.

Mohsenin, N.N., 1986. Physical properties of plant and animal materials. Gordon and Breach, New York, NY, USA.

Olajide, J.D. and Ade-Omowaye, B.I.O., 1999. Some physical properties of locust bean seed. Journal of Agricultural Engineering Research 74: 213-215.

Owolarafe, O.K. and Shotonde, H.O., 2004. Some physical properties of fresh okro fruit. Journal of Food Engineering 63: 299-302.

Pallottino, F., Costa, C., Menesatti, P. and Moresi, M., 2011. Assessment of the mechanical properties of Tarocco orange fruit under parallel plate compression. Journal of Food Engineering 103: 308-316.

Suchy, P. Jr., Strakova, E., Kummer, V., Herzig, I., Pisarikova, V., Blechova, R., Maskova, J., 2008. Hepatoprotective effects of milk thistle (*Silybum marianum*) seed cakes during the chicken broiler fattening. Acta Veterinaria Brno 77: 31-38.